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(54) Getter for Glow Discharge Devices

(57) A getter for a glow discharge device in the form of an electrode 12 for that device, the electrode having at least a surface 30 composed of a gettering material, which surface, in use, is exposed to the glow discharge. As particularly described, the getting material may be Zr, Ti or an aluminium/zirconium alloy formed, for example, on the internal surface of a hollow frusto-ellipsoidal cathode 12, Figure 3, or on the surface of an anode 7 or 8 of a ring laser gyroscope, Figure 1.

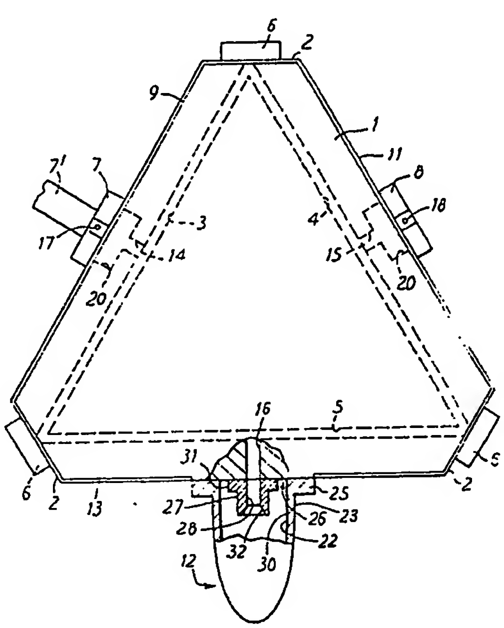

FIG. 1

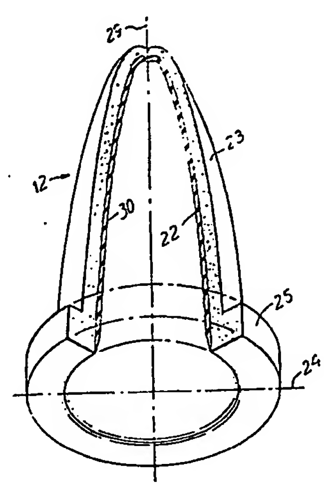

FIG. 3

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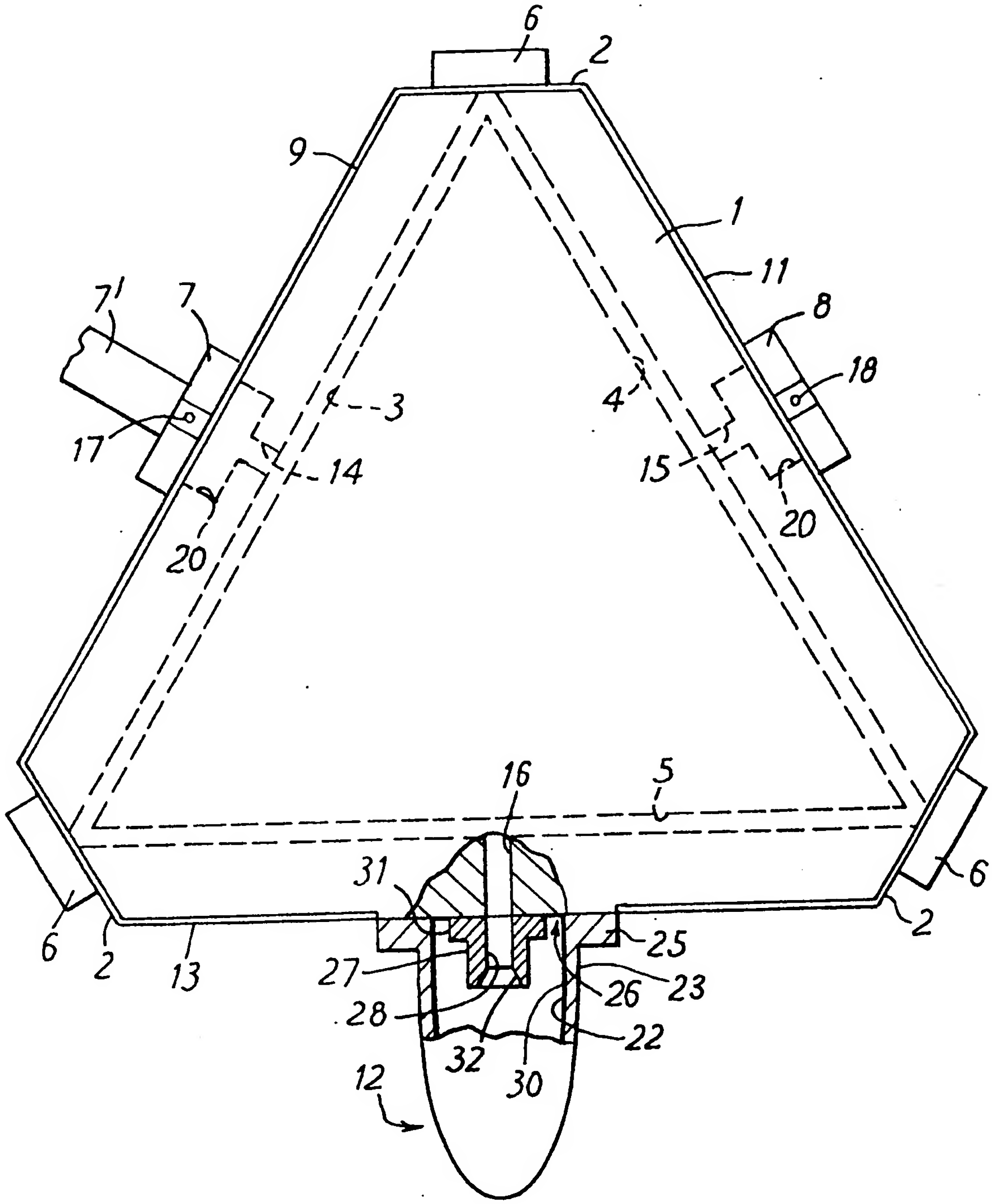
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FIG. 1

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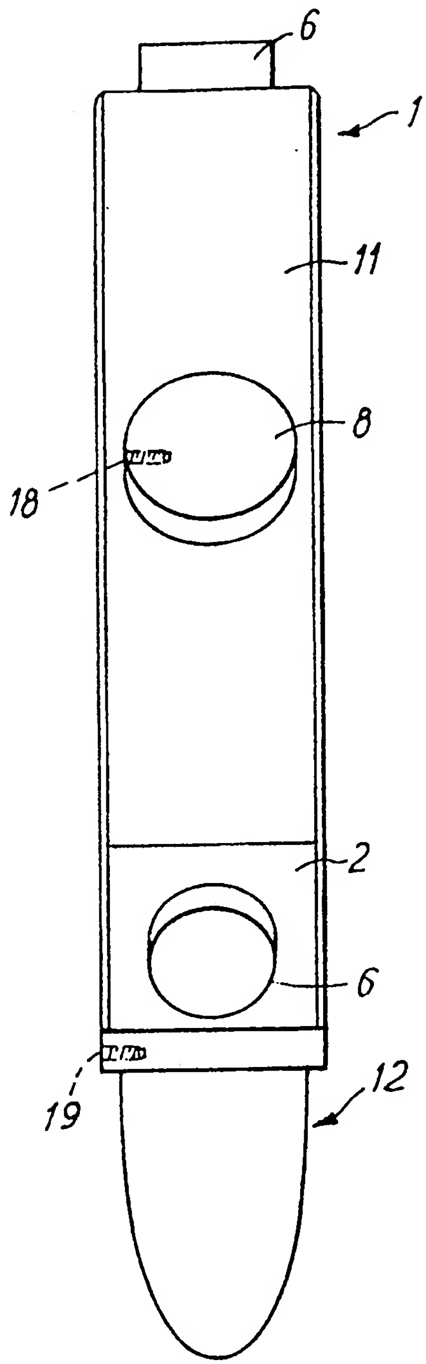

FIG. 2

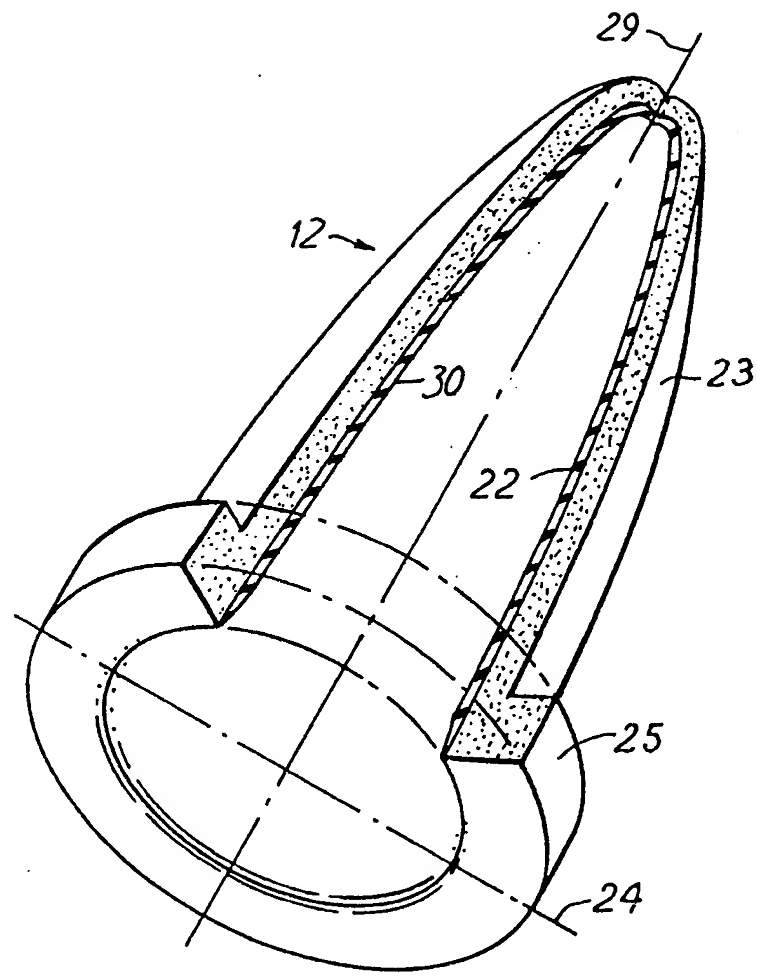

FIG. 3

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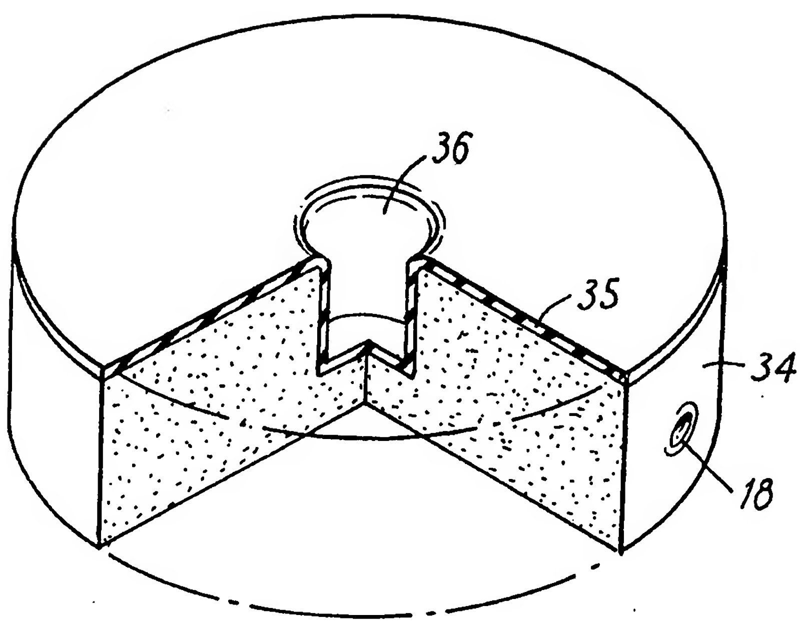

FIG.4

SPECIFICATION
Getters for Glow Discharge Devices

This invention relates to getters for glow discharge devices and has particular, but not exclusive, reference to ring laser gyroscopes.

Metals which have a gettering properly are well known and the more popular ones include barium, titanium, zirconium, molybdenum and niobium. One of the ways metals such as these are prepared to form a getter is by their evaporation in a vacuum (so called "flashed" or "evaporable" getters) to produce a thin film of the metal having a large surface area and a clean surface free from substances other than the base metal, such as oxides, for example. Such a clean fresh metal layer will absorb active gases (e.g. oxygen, nitrogen, water vapour, carbon dioxide, carbon monoxide, and hydrogen) at a rate which will slowly reduce until the surface is saturated with gas. Obviously if such a metal layer is exposed to air, the metal surface will become saturated with gas in a very short time and thence cease to exhibit any gettering property. Therefore, to be effective, the deposition is preferably carried out in situ in the device in which the getter is to be employed and this device must not be allowed subsequently to see large amounts of active gases (such as air).

A second type of known getter is the non-evaporable getter which must be activated in order to operate and which is reactivatable. The activation technique used is to heat the getter, within the device with which it is employed, under vacuum to a high temperature (generally so that it is red hot) and on subsequent cooling the getter will pump active gases in a manner similar to that of the evaporable getter. Pumping continues until the getter surface is saturated, whereupon reactivation can be effected by reheating the getter. This cycle may be repeated until the whole of the volume of the getter material is saturated with gas. In operation, chemical compounds (oxides, nitrides etc.) are formed between the getter material and the absorbed active gases, except for hydrogen, which exists in solid solution. The hydrogen is released when the getter is reactivated and is subsequently reabsorbed, whilst the other active gases, once gettered, are not released.

The only way to activate a non-evaporable getter is by the application of heat, preferably to red heat but certainly to 400°C below which temperature essentially no activation occurs. These getters will continuously pump active gases and do not rely on any discharge being present for this function. In particular, such getters are very useful in an inert gas filled glow discharge device as they remove active impurity gases whilst leaving the insert gases but suffer from the disadvantage of requiring electrical reactivation which necessitates the provision of electrical leads which need to extend into the glow discharge device. Furthermore, there is the disadvantage of having to mount the getter in or on the glow discharge device with the attendant sealing problems and cost.

Another form of getter is the ion pump. This device works on the principle of a Penning gauge, wherein a strong magnetic field is applied perpendicularly to a discharge running from anode to cathode. The magnetic field causes the electrons to spiral so as to increase their mean free path before striking the walls of the container. Trapped ions, of very high energy (typically 5—10 KeV) at very low pressure, strike the cathode (usually made of titanium) at an oblique angle of incidence. The combination of a high energy and oblique incidence angle causes sputtering of the titanium so as continually to expose a fresh surface of titanium which acts as a getter. The sputtered titanium may be redeposited on the cathode causing burial of the gettered gases. The ion pump therefore has two principal mechanisms of operation namely, sputtering causing gas burial, and gettering. However an ion pump only works efficiently for an acceptable life span at very low pressures (less than 10^{-2} Torr) because the necessary large means free paths and very high energy of the ions cannot be achieved at higher pressures.

According to the present invention there is provided a getter for a glow discharge device in the form of an electrode for that device, the electrode having at least a surface composed of a gettering material, which surface, in use, is exposed to the glow discharge.

Thus the broad aspect of the present invention is the combination of an electrode for a glow discharge device with a getter which has previously been a separate component. The main advantage of this combination is that additional electrical leads for the getter are avoided as the electrode is already supplied therewith but even the existing leads do not have to carry current sufficient to heat the getter for activation and reactivation. Thus the combined assembly is cheaper and is more reliable than two separate components. Furthermore, one seal is required relative to the glow discharge device which also produces a cost saving and further increases reliability.

A getter in accordance with the invention combines properties of the ion pump with those of the discrete non-evaporable getter, whereby it is reactivatable and can function even in the absence of glow discharge in the glow discharge device to which it is fitted. The reason why a getter according to the present invention does not require activation from an external supply is that it has been found that activation can be effected by the glow discharge of the glow discharge device. This is as a result of one or more of the following mechanisms:—

1) Local heating causing diffusion of the chemical compounds resulting from the gettering action from the getter surface into the bulk of the getter material.

2) The operation of the glow discharge at as low a pressure as possible by which the energy of

the incident ions is maximised allowing sputtering to take place so that a clean metal surface is continually exposed.

3) Release of surface layers of gas by inert gas ion bombardment.

Having activated the getter material by one of the above three mechanisms, it will subsequently pump active gases, even in the absence of a discharge, by gettering them.

The electrode having the gettering surface may be an anode or a cathode although there is some preference for the latter because normally the cathode has a greater working surface area (and hence the larger the gettering surface) and reactivation of the gettering surface takes place when the glow discharge device, to which the cathode is fitted, is operated. When the getter is in the form of an anode, then initial activation, and subsequent reactivation, of the gettering surface has to be effected by reversing the discharge for a short period by reversing the roles of the anode and cathode.

According to another aspect of the present invention there is provided a glow discharge device having at least two electrodes of which at least one also functions as a getter and has at least a surface composed of a gettering material, which surface is exposed to the glow discharge in use of the device.

The glow discharge device may be fitted with one cathode and two anodes and the cathode alone may have a getter surface. Alternatively, the two anodes may have getter surfaces with the advantage that the cathode can be made from a material, such as aluminium alloy, having known good cathodic properties and a long life. In a further alternative arrangement the cathode and the two anodes (or the one anode if such is provided) may each have a getter surface.

The or each getter surface is preferably activated in situ in the glow discharge device and this may be achieved using a low pressure gas discharge in order to effect efficient activation due to the ability to provide large mean free paths for the ions at low pressure which give rise to a very clean, and hence active, getter surface as explained above. Preferably, the low pressure gas discharge is effected in the presence of an inert gas, and ideally in the presence of the heavier inert gases such as xenon, krypton, argon, and neon. The high mass of the heavier inert gases such as xenon imply that sputtering is very readily accomplished due to its high ion momentum. The mean free path may be further increased, as explained above, by applying a magnetic field across the glow discharge during the low pressure activation process.

Once the activation of the or each gettering surface has been effected, the inert gas is pumped out of the glow discharge device, together with any impurities, and replaced by an inert gas with which the device is required to operate, the gas being at the desired pressure which is normally higher than that at which initial getter activation took place. At this higher pressure sputtering will, to some extent, be suppressed due to the lower energy of the ions, whereby the electrode concerned will exhibit the normal anodic or cathodic property, as appropriate. Alternatively, the glow discharge device can be maintained substantially evacuated once the inert gas at low pressure has been removed.

The materials used to provide the getter surface may be of any of the known gettering materials although zirconium and titanium have been found particularly useful especially in the context of lasers in general and ring laser gyroscopes in particular as they have a large absorption capacity for hydrogen which is the impurity which most quickly causes a lasing action to cease and also has a low sputtering rate at the operating pressure. Alternatively, the getter may be composed throughout of a gettering material such as an aluminium/zirconium alloy, for example.

Getters for glow discharge devices and a glow discharge device in the form of a laser gyroscope, each in accordance with the present invention, will now be described in greater detail, by way of example, with reference to the accompanying drawings, in which:—

Figure 1 is a schematic plan view of the laser gyroscope,

Figure 2 is a view from the right of Figure 1,

Figure 3 is a perspective view, to a larger scale and partly in section, of a getter of the laser gyroscope of Figure 1, and

Figure 4 is a perspective view, to a larger scale, and partly in section, of an alternative form of getter for the laser gyroscope of Figure 1.

Referring to Figures 1 and 2, the cavity of the laser gyroscope is constructed from a block 1 of a material which is non-metallic and has a low coefficient of expansion. A preferred material is that known under the trade name Zerodur. The block 1 is in the shape of an equilateral triangle, as seen in plan view, with the apices cut at right angles to the respective bisectors to provide planar mounting surfaces 2. The block 1 is drilled parallel to each side to provide three limbs 3, 4 and 5 which together form the so-called cavity of the laser gyroscope in which glow discharge or, more specifically, lasing takes place. The cavity is continuous by virtue of the limbs 3, 4 and 5 extending from one mounting surface 2 to another, whereby two limbs intersect at each surface 2. A mirror 6 is sealed to each surface 2.

Communicating with the cavity are two anodes 7 and 8 mounted mid-way along sides 9 and 11, respectively of the block 1, and a cathode 12 mounted mid-way along the side 13 of the block. The anodes 7 and 8 and the cathode 12 are sealed in a gas-tight manner to the block 1, as are the mirrors 6, and communicate with the cavity through respective bores 14, 15 and 16 extending between the associated limbs 3, 4 and 5 and sides 9, 11 and 13. The bores 14 and 15 may each be counterbored at 20 to maximise the surface areas of the anodes 7 and 8 which are exposed to the glow discharge in cavity for a

reason to be discussed. The cavity is filled with an inert gas, typically a mixture of helium and neon. Each anode 7 and 8 is provided with a threaded bore 17 and 18, respectively, (Figure 1) to receive an electrical contact (not shown). Since the cavity is permanently sealed once it has been filled with the inert gas, it is essential to maintain the purity of the gas otherwise once the gas becomes degraded beyond a certain limit, it is impossible to effect lasing. To this end, a getter is provided which is constructed in accordance with the present invention as will now be described.

Referring more specifically to Figure 3, the getter is in fact the cathode 12. The basic construction of the cathode 12 is that it has a hollow body open at one end with both the interior working surface 22 (i.e. cathodic surface) and the exterior surface 23 substantially frusto-ellipsoidal in the sense that the cathode is an ellipsoid cut into half along the minor axis 24. A flange 25 is formed at the open end of the cathode 12 by which the latter is mounted on, and sealed to, the block 1. A threaded bore 19 (Figure 2) is provided in the flange 25 for the reception of an electrical contact (not shown). The cathode 12 is composed of an aluminium alloy (preferably to British Standard L65—American Standard 2024) but can be made of any material having cathodic properties. The method of manufacture may be by machining from the solid or by spinning from sheet material, for example, and it is not necessary to have the exterior surface 23 of frusto-ellipsoidal shape. However, to have a frusto-ellipsoidal exterior surface gives a weight reduction which can be important in relation to providing a good seal between the cathode 12 and block 1 in that the less weight the seal has to support the better.

Since the mounting of the cathode 12 on the block 1 gives rise to a discontinuity in the interior working surface 22 by virtue of the "corner" 26 at the cathode/block interface, it is desirable to shield the discontinuity so that it is in fact eliminated from the cathode working surface 22 and to this end a re-entry member 27 is provided (Figure 1). The re-entry member 27 is tubular, having an axial bore 28 concident with the major axis 29 of the ellipsoid and formed with a flange 31 by which it is mounted on the block 1 such that the bore 28 is in alignment with the bore 16 in the block. The bore 28 is counterbored at 32 at the end remote from the block 1 such that the counterbore flares outwardly from the main bore 28 into the interior of the cathode 12.

The interior working surface 22 of the cathode 12 cs coated with a layer 30 of zirconium which provides the gettering function. The layer 30 of zirconium is put down by vacuum deposition but other techniques may be employed. The combined cathode and getter 12 will normally require activation of the getter material, i.e. the zirconium layer 30, as the latter may be exposed to air after deposition, whereby it has become saturated with active gases and probably formed oxides, nitrides or other anti-gettering substances.

The activation of the zirconium layer 30 is preferably carried out in situ in the laser gyroscope cavity and to this end the latter is filled with xenon at a pressure of about 10^{-3} Torr for which purpose the anode 7 is combined with a fill tube 7′. The anodes 7 and 8 and the cathode 12 are then energised to effect lasing in the laser gyroscope cavity. The zirconium layer 30 is thus "cleaned" by sputtering and the xenon, together with any released impurities, is pumped out of the cavity and replaced by the helium/neon mixture at a higher pressure of up to about 10 Torr, care being taken not to expose the zirconium layer 30 to air or any other active gas. The fill tube 7′ is then sealed by a glass "tip-off" technique or a metal cold weld pinch off, for example.

At the higher operating pressure of up to 10 Torr sputtering of the zirconium layer 30 is in general suppressed compared with that which takes place during the initial activation of the getter layer 30 but still takes place to some extent to permit the gettering as explained above in connection with the three mechanisms which result in activation of the gettering surface in the presence of glow discharge. However, the sputtering is such that the cathode 12 still exhibits good cathodic properties for a long life performance. The gettering property of the zirconium layer 30 pertains even when the anodes 7 and 8 and the cathode are de-energised although the layer will in due course become saturated. However, once the anodes 7 and 8 and the cathode 12 are re-energised to effect lasing, the layer 30 is reactivated and gettering resumes. Thus the combined cathode and getter 12 provides very satisfactory cathodic and gettering properties and offers the following advantages:—

1. The cathode exposes a relatively large (compared with the individual anodes 7 and 8) surface area to the helium/neon gas mixture in the cavity which is desirable since the gettering rate and capacity is proportional to the surface area of the getter (i.e. the layer 30 in this instance).

2. Due to the high ionization potential of the inert gases and charge exchange reactions, the lower ionization potential impurities (e.g. CO, H_2O, H_2O_2) are concentrated as ions at the cathode so the proportion of impurity ions striking the cathode is very much higher than the impurity levels of the atoms within the discharge. The impurity ions are then burned within the cathode and chemically combined.

3. There is avoided the need for a separate getter which normally has to be sealed in a gas-tight manner to the laser gyroscope cavity with the attendant cost and reliability problems.

In the illustrated embodiment the length of each limb 3, 4 and 5 of the gyroscope cavity is 14.3 mm and the size of the cathode 12 is such that the interior surface 18 has a semi-major axis of 55 mm and a semi-minor axis of 12 mm giving an actual working surface area of 40 cm^2. With these dimensions and the aluminium alloy construction, the cathode 12 has been found to sustain a glow discharge in the gyroscope cavity down to 0.025

mA cm^{-2}, allowing a current of 4 mA to be used at a current density below 0.1 mA cm^{-2}.

In operation of the laser gyroscope, the anodes 7 and 8 and the cathode 12 are energised such as to effect and maintain lasing of the helium/neon mixture, or other gas, contained within the cavity and hence provide contra-rotating beams of light as is conventional in laser gyroscopes and which are directed around the cavity by the mirrors 6. The frusto-ellipsoidal working surface 22 of the cathode 12 has been found to exhibit a low sputtering characteristic, particularly with the use of the re-entry member 27, and to exhibit a good discharge oscillation or noise characteristic as is more fully described and claimed in co-pending Patent Application No. (B.5042). Nevertheless, as already discussed, acceptable gettering properties are also exhibited by the combined cathode and getter, the latter being essential because once the cavity has been sealed, it is not possible to purge it of any contaminated gases as it is in many other forms of glow discharge devices.

The getter layer 30 of the cathode 12 may be of any of the well known getter materials but in the context of laser gyroscopes, either zirconium or titanium is preferred since each has a large absorption capacity for hydrogen which is the impurity in a helium/neon laser which quickly degrades the gas to a level which causes the lasing action to cease. Instead of using the aluminium alloy to British Standard L65 for the cathode 12, an aluminium/zirconium alloy can be used which means that the separate zirconium layer 30 can be dispensed with whilst achieving a faster gettering rate.

It will be appreciated that Figures 1 and 2 only show the basic component of the laser gyro and this only schematically. A getter constructed in accordance with the invention can be employed in any form of laser gyro and indeed with any laser of other type of glow discharge device.

In an alternative arrangement, the embodiment of Figures 1 and 2 may have a normal cathode and the getter may be in the form of an anode. Figure 4 shows such an anode 34 which is the same shape, i.e. of disc form, as the anodes 7 and 8 of the embodiment of Figures 1 and 2. The anode is composed of an aluminium alloy to British Standard L44 and has a vacuum deposited layer 35 of zirconium on one diametral surface in which is formed a blind central aperature 36 which serves to concentrate the anode discharge towards the one point or area for stability purposes. A device other than the aperture 36 can be used to this end but is employed here so as to give symmetry with the other anode equivalent to anode 7 which has the fill tube 7′ and hence requires a central aperture extending through the anode.

The anode 34 of Figure 4 may be used instead of the anode 7 and/or the anode 8 of the embodiment of Figures 1 and 2 and in order to expose the maximum area of the getter layer 35 to the lasing medium, the counterbores 20 in the block 1 are provided. Once the or each anode 34 has been sealed to the block 1, each getter layer 35 has to be activated and the same procedure is adopted as described in relation to the activation of the getter layer 30 of the cathode 12, that is the filling of the laser gyroscope cavity with xenon at low pressure, energising the cathode and anodes to effect lasing, and subsequently replacing the xenon with the required helium/neon mix. The only difference with the procedure is that during the activation in the xenon atmosphere the roles of the cathode 12 and the anodes 34 are reversed so that anodes 34 are used as cathodes which is necessary to effect the desired activation of the getter layer 35. During normal operation of the laser gyroscope, the cathode 12 and the anodes 34 are employed in the normal manner but when the reactivation of the getter layer 35 is required, their roles are reversed again for a short period.

The getter layer 35 may be of any of the known getter materials but, as with the getter layer 30 of the cathode 12, zirconium and titanium are preferred because of their capacity to absorb hydrogen. Alternatively, the anode 35 may be composed of a zirconium/aluminium alloy.

If desired, two anodes 34 can be used instead of the anodes 7 and 8 in the embodiment of Figures 1 and 2 whilst still maintaining the combined cathode and getter 12.

Claims

1. A getter for a glow discharge device in the form of an electrode for that device, the electrode having at least a surface composed of a gettering material, which surface, in use, is exposed to the glow discharge.

2. A getter according to claim 1, wherein the surface of gettering material is vacuum deposited.

3. A getter according to claim 2, wherein the surface of gettering material is composed of zirconium.

4. A getter according to claim 2, wherein the surface of gettering material is composed of titanium.

5. A getter according to any of claims 2 to 4, wherein the electrode is composed of an aluminium alloy.

6. A getter according to claim 1, wherein the electrode is composed of a gettering material.

7. A getter according to claim 6, wherein the electrode is composed of an aluminium/zirconium alloy.

8. A getter according to any of the preceding claims, wherein the electrode is a cathode comprising a hollow body provided with an opening and having an internal working surface which constitutes the surface composed of a gettering material.

9. A getter according to claim 8, wherein the internal working surface is substantially frusto-ellipsoidal.

10. A getter according to claim 9, wherein the internal working surface is semi-ellipsoidal with the opening in the body lying in a plane coincident with the plane containing the minor axis of the ellipsoid.

11. A getter according to claim 9 or 10, wherein a flange is provided around the opening in the body by which the cathode can be mounted on the glow discharge device.

12. A getter according to any of claims 8 to 11, and further comprising a re-entry member disposed within the cathode and operable, in use, to shield the junction of the getter with the glow discharge device to which it is fitted whereby that junction does not form part of the working surface of the cathode.

13. A getter according to claim 12, wherein the re-entry member is tubular and has a longitudinal bore aligned with an axis of the frusto-ellipsoidal working surface, the end of the tubular member which, in use, is disposed remote from the associated glow discharge device being counterbored with the counterbore flaring outwardly from the longitudinal bore into the interior of the cathode.

14. A getter according to any of claims 8 to 13, wherein the exterior surface of the cathode is also of substantially frusto-ellipsoidal shape.

15. A getter according to any of claims 8 to 14 and machined from a solid block of material.

16. A getter according to any of claims 8 to 14 and formed by spinning from sheet material.

17. A getter according to any of claims 1 to 7, wherein the electrode is an anode which is disc shaped and a diametral surface of which constitutes the surface composed of a gettering material.

18. A getter according to claim 17, wherein the anode is formed with an aperture extending from the centre of said diametral surface.

19. A getter according to claim 17 or 18, wherein the anode is combined with a fill tube by which, in use, the associated glow discharge device can be filled with a desired gas.

20. A glow discharge device having at least two electrodes of which at least one also functions as a getter and has at least a surface composed of a gettering material, which surface is exposed to the glow discharge in use of the device.

21. A glow discharge device according to claim 20, wherein the getter is in accordance with any of claims 2 to 7.

22. A glow discharge device according to claims 20 or 21 wherein the getter is in accordance with any of claims 8 to 16.

23. A glow discharge device according to claim 20 or 21, wherein the getter is in accordance with any of claims 17 to 19.

24. A glow discharge device according to claim 20 or 21, wherein each electrode functions as a getter with the or each cathode being a getter in accordance with any of claims 8 to 10 and the or each anode being a getter in accordance with any of claims 17 to 19.

25. A glow discharge device according to any of claims 20 to 24 and in the form of a laser gyroscope.

26. A method of activating the or each getter of a glow discharge device according to any of claims 18 to 22, the method comprising the steps of filling the glow discharge device with an inert gas at a low pressure and energising the electrodes to effect a glow discharge and hence activation of the or each getter, de-energising the electrodes, and removing the inert gas.

27. A method according to claim 26, wherein the inert gas is replaced by another inert gas required for normal operation of the glow discharge device.

28. A method according to claim 26 or 27, wherein the step of energising the electrodes entails reversing the roles of the anode and cathode when the getter is part of the anode.

29. A method according to any of claims 26 to 28, wherein the inert gas is xenon.

30. A method according to any of claims 26 to 29, when appended to claim 27, wherein the pressure of the low pressure inert gas is of the order of 10^{-3} Torr and the pressure of the inert gas used to replace the low pressure inert gas is up to 10 Torr.

31. A getter substantially as herein particularly described with reference to Figures 1 to 3, or to Figure 4, of the accompanying drawings.

32. A laser gyroscope substantially as herein particularly described with reference to Figures 1 to 3, or as modified by Figure 4, of the accompanying drawings.

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